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A cold box for the transport and storage of vaccines

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A cold box capable of maintaining a temperature below +4°C for 1 week was constructed and tested in the laboratory and under field conditions. Cooling is produced by commercial cold packs precooled in a deep-freeze or the freezing compartment of a refrigerator. The box can take approximately 3000 doses of vaccine and is simple, cheap and strong. It is primarily intended for storage of vaccines during field trips by vaccination teams, as an alternative to the refrigerator in regional and peripheral stores in the case of an electrical power failure, and for the delivery of vaccines from regional store to the district.

Vaccination has been used extensively in developed countries over the last few decades for the prevention of a number of important communicable diseases such as poliomyelitis, diphtheria, and measles. The experiences gained in these countries are now being transferred on a gradually increasing scale to the developing world, and the World Health Organization is playing a very active role in this development through its Expanded Programme on Immunization (EPI).

The application of vaccination in developing countries has met with a number of problems of an economic, operational, and technological nature. One of the main problems consist in the refrigerated storage and transportation of vaccines (the so-called " cold chain "). The available technical solutions to this problem are mainly based on the presumption that there is a steady supply of electric power, which is frequently not the case in developing countries. The problem is much more serious for these countries in that many of them have a hot tropical climate and much of the cold chain equipment produced in the developed countries is unsuitable for tropical countries.

Preliminary experience in the EPI indicated that existing technical equipment for the maintenance of the cold chain was, as a rule, too complicated, too fragile, and too expensive. Commercially available cold boxes were too fragile and remained cold for too short a time. The cold boxes to be described were therefore constructed to satisfy the following criteria:

1. Water resistance.

2. Robustness and ability to withstand continual use under rigorous field conditions.

3. Ability to maintain a temperature not exceeding approximately +5°C for 1 week.

4. Cheapness and simplicity, in order to facilitate local production in different countries.

5. Ability to contain approximately 3000 doses of vaccine.

The cold boxes were originally designed for two specific purposes, namely, to store vaccines during field operations lasting approximately 1 week and to serve as an alternative means of storage during temporary power failures in stores where small amounts of vaccine were kept. During the field tests they were found to be useful for the delivery of vaccines from the regional stores to the districts.

The prototype of the box was presented at a WHO Seminar in Ghana in 1974 (*1*). Only slight modifications have been introduced since then. The box has now been tested under field conditions in an EPI feasibility study in Ghana. This test is part of a broader WHO programme for the improvement of the cold chain for vaccines (*2*). A complete

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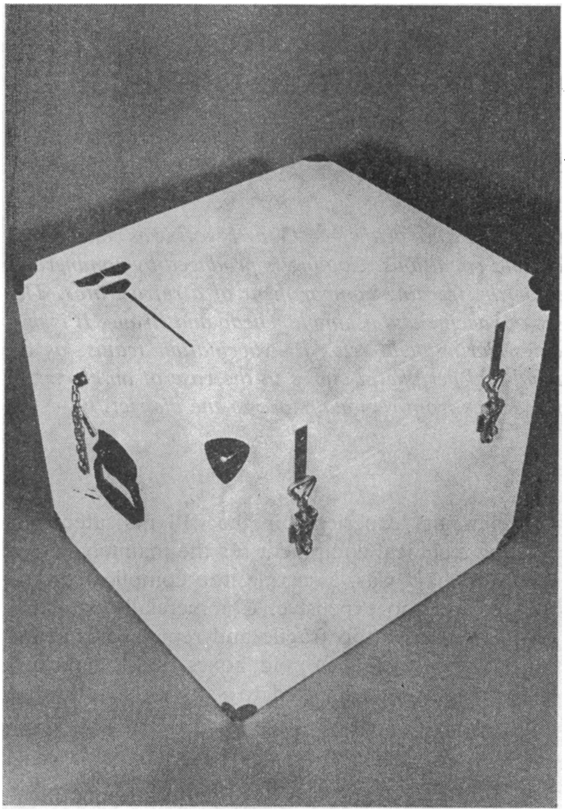

Fig. 1. The small box (type B) with lid closed.

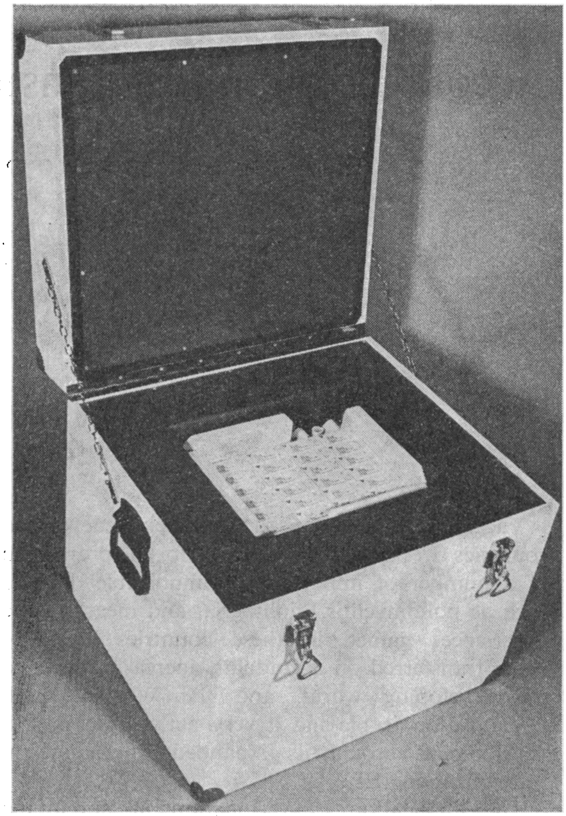

Fig. 2. The small box loaded with vaccines and cold packs except for the top layer of cold packs.

technical description for the production of the box described below is in preparation under this programme.

CONSTRUCTION

The box consists of the following elements (see Fig. 1 and 2):

Outer casing. It is essential that the casing is strong and can resist humidity and insects. For these reasons marine plywood was used.

Insulation. Different kinds of insulating, water-resistant material were tested. Great differences in insulating capacity were found, as shown in Fig. 3. Cellular polyurethane with closed cells was found to be superior and was therefore chosen as the insulating material. It has a density of 30 kg/m³. This material has low values of thermal conductivity, water absorption, and humidity diffusion.

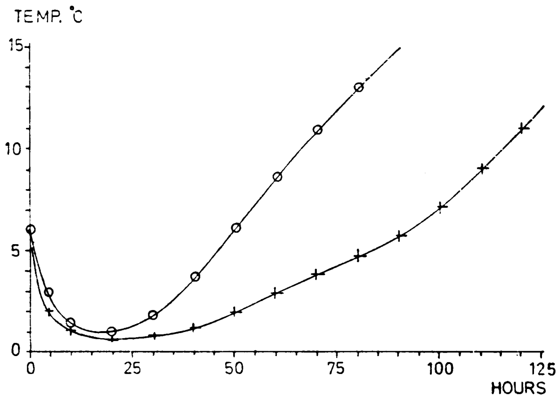

Fig. 3. Insulating capacity of different materials at an ambient temperature of 30–34°C. 0 = cellular polystyrene, + = cellular polyurethane.

Inner lining. PCV is used for this purpose. The joints are glued together.

Lid. The lid is made of the same material as the rest of the box. It is fixed to the rear wall of the box with a piano hinge.

Seal. A seal of ethene–propene rubber is glued to the lid. This makes the lid practically airtight.

Chain stays. These are fixed to the sides of the lid and the box to prevent overstraining the hinge.

Catches. Two catches are fitted to the box in such a way that pressure is exerted on the lid and the seal to keep the box airtight. They are adjustable and can be provided with padlocks.

Handles are fitted to two sides of the box.

Metal caps are screwed on each corner as reinforcement against rough handling.

Glues. An ordinary waterproof glue is used for the wood structure. Insulating material, wood, and PVC are glued together with a neoprene-based glue; this glue is also used for the seal.

COOLING SYSTEM

Cooling is effected by means of commercially available cold packs (" cold dogs ") used for picnic boxes. These consist of plastic bottles filled with water and an additive to increase viscosity. The cooling capacity is almost completely dependent on the consumption of energy for the melting of the ice and the packs can therefore be filled with water only. The outer measurements of each pack are 195 × 120 × 38 mm. They swell during freezing to a thickness of about 50 mm. The cold packs are frozen in a deep-freeze or in the freezing compartment of a refrigerator and are transferred to the box and arranged so that they line the walls and the bottom of the box. The vaccine ampoules are placed in the remaining space and cold packs are finally placed on top of the ampoules (Fig. 2). This arrangement provides the best cooling conditions for the vaccines by establishing a temperature of approximately 0°C in the central space until most of the ice in the cold packs has melted.

It should be noted that killed vaccines containing preservatives, such as DPT and killed poliomyelitis vaccines, should not be allowed to freeze (*1*). These vaccines will freeze if loaded together with cold packs at −20 to −25°C. It is sufficient to leave the packs for 20–30 min at room temperature before transferring them to the cold box to avoid this problem. They will still provide enough cooling, since this is mainly dependent on the melting of the ice.

Table 1. Measurements and weights of the two types of box

Type	Outer measurements (mm)	Inner measurements (mm)	Weight (kg)	
			Empty	Full
A	710 × 560 × 500	480 × 330 × 270	24.7	46.0
B	580 × 510 × 500	350 × 280 × 270	18.0	30.0

MEASUREMENTS, VOLUMES, AND WEIGHTS

Two sizes of box were constructed and tested, one (type A) with a loading capacity of 2500–3000 doses (288 10-ml vials) and the other (type B) with a capacity of 1250–1500 doses. Measurements and weights are shown in Table 1.

TESTING

The boxes were tested in the laboratory as well as in the field. The laboratory tests were run under different experimental conditions. The box was loaded with vaccine and cold packs and the temperature was measured in the centre, in the space between the vaccine and the cold packs, and in the space between the cold packs and the inner wall of the box. In some experiments the box was kept closed during the whole experiment, whereas in others the box was opened a number of times and vaccine vials removed. The ambient temperature and the starting temperature of the cold packs were also varied.

When the box was loaded with cold packs at −20°C, the ambient average temperature was +24°C, and the box was not opened during the experiment, the temperature in the box (regardless of site) remained below 0°C for 2 days, remained at 0°C for 12 days, and rose in 16 days to +8°C (Fig. 4). When the average ambient temperature was raised to +34°C and the temperature of the cold dogs to 0°C, the box was opened six times a day, and every time twelve 10-ml vials were removed, the temperature in the centre of the box remained at 0°C for 5 days and below +4°C for 7 days (Fig. 5). It is evident from Fig. 5 and 6 that the opening of

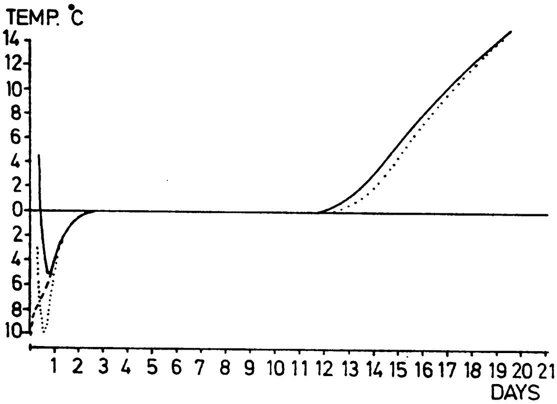

Fig. 4. Test of temperature-retaining capacity. Ambient temperature +24° C, temperature of cold packs —20°C, box not opened. Solid line—centre of the box; broken line—space between vials and cold packs; dotted line—space between cold packs and inner wall.

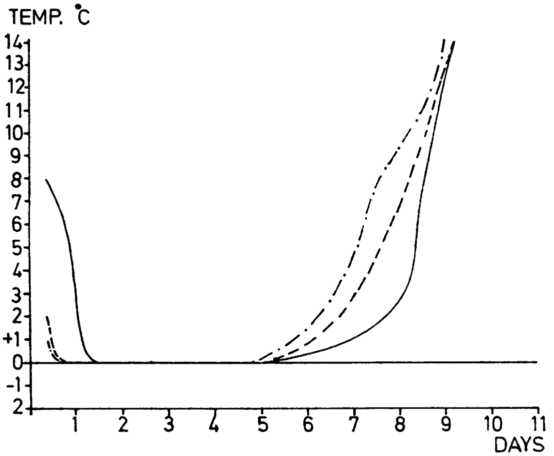

Fig. 5. Test of temperature-retaining capacity. Ambient temperature +34°C, temperature of cold packs ±0°C, box opened and twelve 10-ml vials removed six times a day. Solid line—centre of the box; broken line—space between vials and cold packs; dotted line—space between cold packs and inner wall.

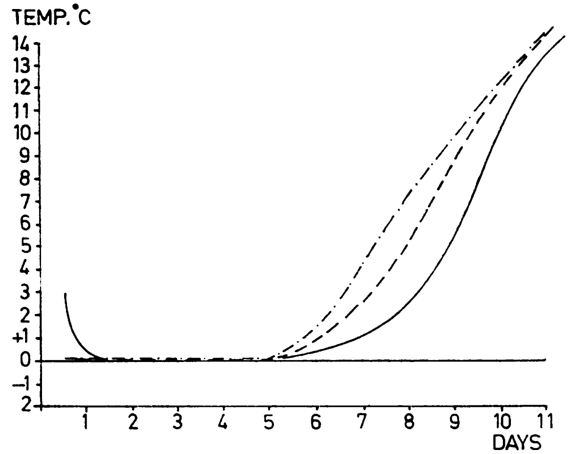

Fig. 6. Test of temperature-retaining capacity. Ambient temperature +34°C, temperature of cold packs ±0°C, box not opened. Solid line—centre of the box; broken line—space between vials and cold packs; dotted line—space between cold packs and inner wall.

the box had no major effect on the temperature-retaining capacity of the box.

The boxes were shipped from Sweden to Ghana in the autumn of 1975. During shipment they were accidentally exposed to a rather rough test: they were transferred from the ship to a store in a harbour that was flooded during a storm and were returned to the National Bacteriological Laboratory of Sweden for checking. No damage was apparent and the boxes were, after cleaning, again shipped to Ghana and subsequently used in a feasibility study in that country.

The boxes have been used in Ghana since 1975, primarily for field trips by mobile vaccination teams lasting for 5 days and as an alternative to refrigerators at the regional level. The casing, catches, chain stays, hinges, and seals, which could be anticipated to be weak points in the construction, were all functioning satisfactorily after 18 months of use. There was no humidity or insect damage. The larger box was found somewhat heavy to carry, but this was essentially its only defect.

DISCUSSION

The maintenance of the cold chain for vaccines is a major problem in many developing countries, particularly in regions where electricity and reliable supplies of gas are not available. These regions are served by mobile vaccination teams, which have to travel and stay out in the field for various periods of time. Such teams have their base in areas where cooling facilities to provide the boxes with the necessary cold packs are available.

As a rule, the teams do not stay in the field for more than a week at a time. The boxes described in this paper seem to be able to solve the cold chain problem satisfactorily under these circumstances. They are strong enough and can maintain the required temperature for a week. Production costs in Sweden are fairly high (approximately US$230 per box). It should be pointed out, however, that the boxes have so far been produced in small numbers and production in larger numbers would very probably result in a lower price per box. Some investment would then have to be made in tools for production of the inner lining and the insulation in one piece for mounting into the outer casing. This would ensure an even quality and minimize the necessary manpower. No advanced technology is involved and local production in many different countries should, therefore, be possible. Locally produced boxes would be cheaper and would save foreign currency. It should be added that no patents have been taken out on the cold box.

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RÉSUMÉ

UNE GLACIÈRE POUR LE TRANSPORT ET LA CONSERVATION DES VACCINS

Pour l'exécution du programme de vaccinations dans les pays en développement, l'un des principaux problèmes à résoudre est le maintien d'une chaîne du froid continue. L'équipement généralement disponible, conçu pour des pays développés jouissant d'un climat tempéré, est souvent trop fragile et trop compliqué à la fois, et trop coûteux tout en n'assurant pas une isolation suffisante dans les conditions climatiques tropicales. C'est surtout à l'occasion des opérations s'effectuant à la périphérie où l'absence d'électricité ou d'un approvisionnement en gaz régulier est fréquente, qu'apparaissent les lacunes de la chaîne du froid.

L'un des maillons de la chaîne est la glacière, qui doit permettre avant tout *a*) de conserver les vaccins pendant la durée des opérations sur le terrain, soit environ une semaine, et *b*) de disposer d'un recours en cas de panne d'électricité.

Le présent article décrit une glacière qui répond à ces objectifs. Fabriquée par le Laboratoire bactériologique national de Stockholm, elle satisfait aux critères suivants:

— résistance à l'eau;

— robustesse à la mesure des exigences d'un usage intensif dans des conditions de terrain difficiles;

— maintien pendant une semaine d'une température n'excédant pas 5°C;

— simplicité et économie de fabrication, et par conséquent possibilité de production dans divers pays;

— contenance suffisante pour un stock de 3000 vaccins.

L'intérieur de la glacière est refroidi au moyen d'« éléments réfrigérants » du commerce. La température de ceux-ci est de −20°C au moment où ils sont mis en place et la température ambiante de +24°C, et si la glacière n'est pas ouverte en cours d'expérience la température demeure au-dessous de 0°C pendant 2 jours à l'intérieur quel que soit le lieu, est encore de 0°C seulement pendant les 10 jours suivants et s'élève au bout de 16 jours à +8°C. Si la température ambiante s'accroît jusqu'à +34°C et celle des éléments réfrigérants à 0°C, la glacière étant ouverte 6 fois par jour pour en retirer chaque fois 12 ampoules, la température est de 0°C au centre de la boîte pendant 5 jours et reste inférieure à +4°C pendant 7 jours. On peut en conclure que l'ouverture répétée n'a pas beaucoup d'effet sur la capacité de la glacière à maintenir un niveau de température adéquat.

Ce type de glacière est en service depuis 1975 au Ghana, notamment pour les déplacements d'une durée de 5 jours des équipes mobiles de vaccination et, au niveau régional, en tant qu'équipement de secours à côté des réfrigérateurs. Elle n'a causé jusqu'à présent aucun problème. Le

revêtement extérieur, les fermoirs, les chaînes de retenue du couvercle, les charnières et le joint de caoutchouc — autant d'éléments qui auraient pu constituer des points faibles — sont tous dans un état satisfaisant après 18 mois d'usage. On n'a pas relevé de traces d'humidité ou d'endommagement causés par des insectes.

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